EROSIONAL PROCESS AND ITS POTENTIAL CONTROL AT THURMOND LAKE

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REFERENCE: Proceedings of the 1999 Georgia Water Resources Conference, held March 30 and 31, 1999, at The University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia 30602-2202.

Abstract. Thurmond Lake is a Corps of Engineers reservoir that, like many other reservoirs, suffers from eroding shorelines. A study of Thurmond found that the complex shoreline configuration controls the occurrence of fetch and concentration of wave energy, and thus of erosional process. Bluff recession, which is the visible and damaging feature of shore erosion, is a consequence of downcutting of the bench. Halting bluff recession requires combating undercut at the bluff's base. Alternative structural and bioengineering stabilization measures are described and evaluated. General guidelines for shoreline installations are given, including the most reliable months for access, the elevation required to protect from wave "runup", the requirement of wings and toes to prevent flanking and undercutting, and selection and installation of plants for bioengineering.

INTRODUCTION

In the last half-century the United States has gone through a massive reservoir construction effort; today the cycle of construction is essentially complete. More than half of all large lakes in the country, and essentially all of those in Georgia, are now man-made (van der Leeden et al., 1990, p. 186-187).

Reservoir shorelines today are numerous and extensive. And they are "new" in every sense, with erosion, reconfiguration of topography, and primary succession actively underway. The design of erosion controls along reservoir shorelines must be based on understanding of the dynamic environment in which they are placed.

The study reported in this paper characterized the occurrence and variation of reservoir shoreline erosion, evaluated alternative stabilization measures, and developed installation guidelines specifically for this type of environment.

The study focused on Thurmond Lake (formerly Clark Hill Lake) on the Piedmont portion of the Savannah River. The Army Corps of Engineers constructed Thurmond in 1953 for flood control, power generation, and recreation. Thurmond is the largest Corps reservoir east of the Mississippi River, with 70,000 acres of water and 1,100 miles of shoreline. Although Thurmond is located in a largely rural area, it is the tenth most visited Corps lake in the United States.

After 45 years, it is acknowledged that portions of Thurmond's shores are severely eroding. Vertical bluffs have been carved at many places, progressively encroaching on public and private lands and, in some places, threatening to undermine structures. Below the bluffs, ecological succession is continually set back by shifting substrate. Eroded soil becomes suspended sediment which impairs lake water quality and threatens fish spawning habitat. Redeposited sediment shorten's the lake's useful life.

BACKGROUND AND RELATED WORK

The Corps of Engineers (1981; Corps of Engineers North Central Division, undated) previously outlined alternative potential methods of shoreline erosion control. However, those manuals did not address the distinctive erosional setting of "new" reservoirs.

Nor did the previous manuals include bioengineering — the combination of living and structural materials — among the possible stabilization approaches. Living vegetation in bioengineering installations increases a structure's strength, durability and reliability (Schiechtl and Stern, 1997; Sotir and Nunnally, 1995). Roots add tensile strength. Stems and branches dissipate wave energy. Growing vegetation sprouts to fill open areas.

This paper fills gaps in the previous work by characterizing the distinctive setting of Thurmond's erosion, evaluating alternative erosion control methods and installation guidelines in the context of that setting, and extending available approaches to include bioengineering. Further technical details are documented in Ferguson (1997) and Ferguson and Overend (1998).

METHOD

The study began with characterization of the lake and its region, and visits to Thurmond shoreline sites of various erosional states. Literature on shoreline geomorphology, values and stabilization methods was reviewed. On three selected shoreline sites, the erosional history and status were reviewed in detail, using site visits and examination of archival aerial photographs. Hypothetical designs were produced to explore the appropriateness of potential treatments in various condi-

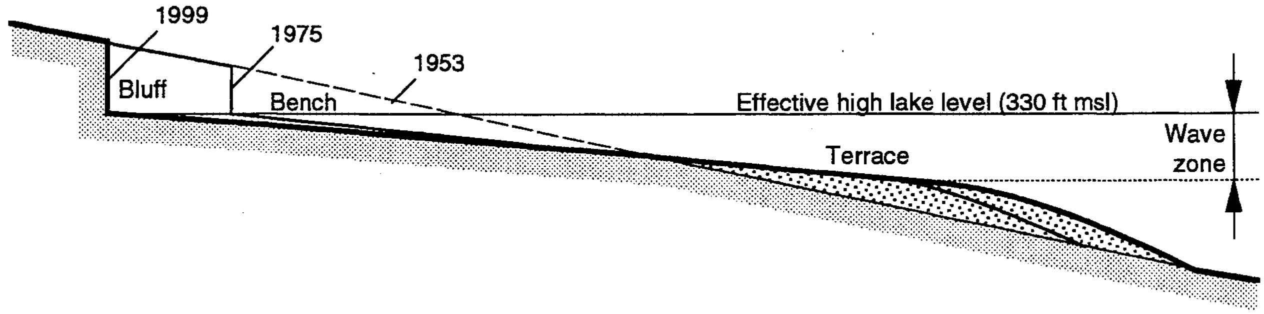

Figure 1. Progressive development of bluff, bench and terrace.

tions of shoreline land use and erosional process. The results were constructively critiqued by the Corps' management staff, and by the public through an "open house" public forum and widely solicited letters from local congressional offices and state and county agencies.

CONCLUSIONS 1: SETTING AND OCCURRENCE OF EROSION

Thurmond's shore is a submerged shore, formed by the abrupt rise in water level with the construction of the dam. Like other submerged shores (Easterbrook, 1993, p. 441), Thurmond's is very irregular in outline.

The significant erosive agent on Thurmond is the energy of wind-driven waves. Before construction of the dam, the only alluvial process in the landscape had been in the floodplain of the Savannah River. The closure of the dam in 1953 abruptly raised the water level and expanded the fetch, the open-water distance over which the wind flows before reaching a shoreline. The erosive energy of waves accumulates as the wind flows over the lake's surface, to be released in concentrated form at the shore. During events of similar frequency, the erosive energy in Thurmond's wind-driven waves can be 10,000 times greater than that in the rainfall to which the hill slopes were previously adapted (Ferguson and Overend, 1998). The native terrestrial landscape was out of equilibrium with its powerful new environment, and began a process of adjustment. After 45 years the process is still far from complete. That is the reason Thurmond's shorelines are eroding.

The complex shoreline configuration controls the distribution of fetch, and thus of erosive wave energy (Army Corps of Engineers, 1981, p. 47; Bloom, 1969, p. 108-109). The fetch is small in the numerous inlets and coves. In contrast, where peninsulas project into the lake's open water, fetch exceeds 3 miles, and reaches 9 miles on certain headlands in the broad southern portion of the lake. The most noticeably eroding bluffs are concentrated in the shourthern third of the lake, even though the shoreline slopes here are typically gentler than those in the northern-two thirds, where fetch and wave energy are smaller.

The shoreline configuration further controls the local convergence of wave energy (Bloom, 1969, p. 108-109). At promontories, wave energy converges, cutting a bench in the wave zone (Figure 1). As waves cut down the bench, they attack the base of the bluff at Thurmond's effective high-water elevation of about 330 ft msl. When the bluff is sufficiently undercut, material shears off and falls onto the bench. Further waves disintegrate the fallen debris, and remove it from the energetic wave zone. Thus the retreat of the bluff, which is the visible and prominently damaging feature of shoreline erosion, is a consequence of the hidden underwater downcutting of the bench. The dramatic 20 to 30 ft high bluffs on steeply sloping sites have receded at about 2 ft per year. On gently sloping sites, some small bluffs now 5 ft high have receded at more than 10 ft per year.

In contrast, the numerous inlets and coves typically experience small, divergent waves. The coves are being filled with sand eroded from the headlands and transported into coves by wave-generated longshore currents. Other eroded sand is washed into depositional terraces just below the wave zone.

Thurmond's water level varies with the Corps' management in accord with the reservoir's functional purposes (Army Corps of Engineers, undated). The lake is typically drawn down during the autumn to prepare for storage of winter and spring flood waters. Soon after reaching an annual low in the winter, the lake can rise abruptly in early spring. During the summer the water is maintained near 330 ft msl, to provide recreational access and to protect the shallow-water spawning habitat of game fish. As the lake rises and falls, it effectively deepens the wave zone below the summer pool level from 3 ft to about 15 ft, and proportionally extends the erosional and depositional formation of benches and terraces toward the center of the lake.

Thurmond's erosional development is following a pattern that characterizes submerged shores in general (Larson and Birkeland 1982, p. 514-517). Bluffs at headlands characteristically alternate with beaches at coves. Theoretically, the rate of erosion is tending to slow down as the shore approaches, very gradually, a more smooth, gentle, simple, erosionally mature form. However, this is a geomorphic process that will not be complete within any ordinary human time frame.

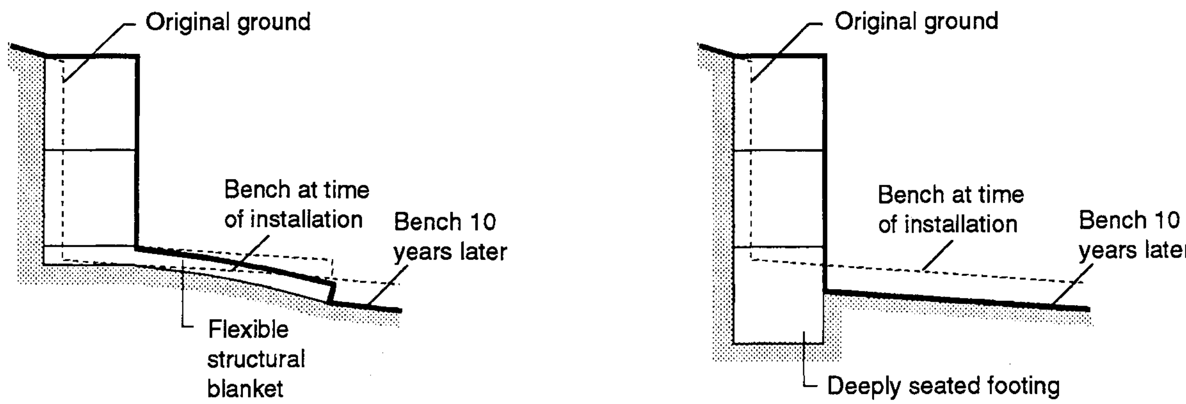

Figure 2. Two approaches to protection from undercutting.

CONCLUSIONS 2: ALTERNATIVE STABILIZATION MEASURES

Halting bluff recession requires combating the bench downcutting that undercuts the base of the bluff. The approaches considered most closely at Thurmond are described here, with evaluations of their stabilization effectiveness. Data for structural measures are mostly from previous Corps of Engineers manuals (1981; North Central Division, undated); data for bioengineering measures are primarily from Schiectl and Stern (1997), Sotir and Nunnally (1995), and Westmacott (1985a and 1985b). Further technical details and evaluation in terms of ease of construction, ecological habitat, appearance, and accessibility are given in Ferguson (1997) and Ferguson and Overend (1998).

Brush bundles. Brush bundles are assembled from live hardwood cuttings. Although they can be anchored, they have no structural protection from wave undercutting, so they are suited only to shorelines with low wave energy. They are further limited to sites with soil substrate, not eroded to bedrock. This means that their application is limited to depositional beaches, not eroding headlands.

Riprap. Riprap relies on the weight of stones to prevent displacement; there is no binding force. The rock must be large enough to be immovable even by the largest expected waves. The rock must be underlain by some type of filter to prevent soil from being eroded out between the rocks. A riprap structure has the advantage of flexibility; it maintains some stabilization value even after some undercutting and differential settlement. Inserting willow cuttings through the rock layer into the underlying soil can bind stone and soil layers together.

Gabions. Gabion structures are masses of relatively small, numerous stones bound in wire baskets. They must be backed by a filter fabric or filter layer. The mass of gabions holds them in place. Their flexibility allows them to tolerate some differential settlement. Their porosity, flexibility, great weight, and tensile strength makes them one of the most reliable of shore protection works. Live hardwood cuttings that root in gabions and underlying soil further strengthen the structure and prolong its life. Choking the stone voids around the cuttings with soil helps assure successful rooting; the soil is unlikely to be washed out of relatively small voids deep within a gabion structure.

Constructed walls. Constructed walls other than gabions rely on cantilevered piers or the tension of anchor rods for stability. They depend stringently on the adequacy of their materials and construction for effectiveness and durability. Installation may require concrete footings or driving of piles. Rigid construction is intolerant of differential settlement. Site-specific design by a qualified professional person is mandatory.

CONCLUSIONS 3: GENERAL INSTALLATION GUIDELINES

Given Thurmond's distinctive setting, the following guidelines apply to all shoreline installations on the lake. Technical details are given in Ferguson (1997) and Ferguson and Overend (1998).

Time of installation. The most reliable time for access to the base of the bluff for installation is in the early fall and winter, beginning as soon as the lake begins its annual drawdown in August or September. At other times of year, the lake level is at its high summer pool, or could rise abruptly with unforeseen floods.

Top of protection from waves. The height of a shoreline structure protects it from direct attack by large waves during high water, and from the "runup" as waves carry themselves up shoreline slopes. Recommended minimum top elevations were calculated based on expected high water levels, wave height, and runup. For fetch of 2 to 9 miles, they range from 337.5 to 338.0 ft msl, with the higher elevations being for the greater fetch.

Toe and flank protection. To combat undercutting, two forms of toe protection are shown in Figure 2. A flexible structural blanket slumps into places where substrate is washed out, preventing bench erosion from extending under the structure. As an alternative, the foundation of the structure can be excavated below the level of bench scour anticipated during the life of the structure. To combat erosion around the edges of the structure, "wings" — landward extension of the structure — protect the structure as flanking waves erode away adjacent unprotected soil.

Bioengineering materials. In Thurmond's dynamic hydrologic and sedimentary environment, living vegetation for bioengineering must be able to root from hardwood cuttings, withstand periodic inundation, survive and regenerate when roots are buried by sediment, and throw up dense thickets of young growth whenever cut or broken (Westmacott, 1985b). Among plants native to Thurmond Lake, black willow (Salix nigra) is known to have all of these qualities, and has given favorable experience in bioengineering projects throughout eastern North America. Living material suitable for collection can be found growing in some bays accessible by boat or small truck, or ordered from commercial nurseries. Willow harvesting and placement are severely limited to the dormant season of November through February (Westmacott, 1985b). Fortunately, the dormant season overlaps with Thurmond's period of shoreline accessibility in November, December and January.

DISCUSSION AND RECOMMENDATIONS

The developmental process that the construction of Thurmond Lake initiated must inevitably continue, until the erosion reaches hard bedrock or some equilibrium limit of bench extension. Geomorphic maturation of Thurmond's shorelines will not be complete within any ordinary human time frame. Benches will continue to be cut down, and with them bluffs will continue to recede, taking property and encroaching on structures.

In future shoreline stabilization projects on reservoirs like Thurmond Lake, the type of treatment to be used and the decision whether to install any at all should be based on understanding of the distinctive reservoir setting; this understanding focuses attention on the sites where wave energy is greatest, the appropriateness of alternative stabilization measures, and informed guidelines for time allowances and construction techniques. They should also be based on site-specific objectives and resources that vary with land use, ownership character, and property value.

ACKNOWLEDGEMENTS

The research reported in this paper was supported by the U.S. Army Corps of Engineers, Savannah District. Mitchell Overend of the Savannah District oversaw the project and provided guidance and information. The initial work was performed by University of Georgia landscape architectural students Rajesh George, Jennifer Horn, Carey June, Paige LaBorde, Brent Lloyd, Annette Loomis, Elizabeth Midgley, Christina Moore, Angie O'Shea, Tommie Taylor, Robert (Alfie) Vick, Philip Wislar, and David Zaparanick. The Georgia Crushed Stone Association and the Georgia Soil and Water Conservation Commission provided technical information.

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